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In re Patent Application of Jacobus HAARTSEN Application No.: 09/840,399 Filed: April 23, 2001 For: Method, Apparatus and System for Synchronization in Radio Communication Systems	Group Art Unit: 2681 Examiner: Tan H. Trinh Confirmation No.: 4491

DECLARATION UNDER 37 C.F.R. § 1.131

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Jacobus HAARTSEN, declare that:

1. I am the inventor of the subject matter disclosed and claimed in the above-referenced patent application.

2. The claimed invention was reduced to practice in the United States prior to the March 7, 2000, effective filing date, of U.S. Patent Application Publication No. 2003/0002495 to Shahar et al., cited by the Patent Office in the above-identified application.

3. Attached Exhibit A is a redacted copy of the invention disclosure evidencing the reduction to practice of the invention. The invention disclosure was completed prior to March 7, 2000, and corresponds to the invention broadly disclosed and claimed in the above-identified patent application.

4. I hereby declare that all statements made herein of my own knowledge are true and that all statements made upon information and belief are believed to be true; and further that these statements and the like so made are punishable by fine or imprisonment, or both, under 18 United States Code section 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Jacobus Haartsen

Date: July 12, 2004

EXHIBIT A

patent disclosure for

METHOD AND APPARATUS FOR SYNCHRONIZATION IN RADIO SYSTEMS

Inventor: Jacobus Cornelis Haartsen

1. FIELD OF THE INVENTION

This invention relates to radio communications in general. In particular, the invention deals with synchronization radio receivers.

2. BACKGROUND

In the last decades, progress in radio and VLSI technology has fostered widespread use of radio communications in consumer applications. Portable devices, such as mobile radios, can now be produced having acceptable cost, size and power consumption. Mobile phone communications for the consumer market started with phone system derived from the police and rescue services and was based on an analog technology improved and optimized in the seventies and eighties. These systems led to the first analog phone systems for public usage such as AMPS, NMT and TACS. The usage of mobile phones really took off in the nineties with the introduction of mobile phone systems based on digital technology like GSM, D-AMPS and PDC. Although radio technology is today focused mainly on voice communications (e.g. with respect to handheld radios), this field will likely expand in the near future to provide greater information flow to and from other types of nomadic and stationary devices. More specifically, it is likely that further advances in technology will provide very inexpensive radio equipment, which can easily be integrated into many devices. This will reduce the number of cables currently used. For instance, radio communication can eliminate or reduce the number of cables used to connect master devices with their respective peripherals.

Synchronization is a crucial element in radio communications. In order to properly recover the information stream sent by the transmitter, the receiver has to synchronize

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to the incoming signals. For continuous wave (CW) radio systems, for example the old analog cordless phone systems but also the more modern direct-sequence CDMA systems, synchronization only happens once at the beginning of the connection. When the connection is established, the receiver initially synchronizes to the transmitter; thereafter, a tracking mechanism keeps the receiver in synchrony to the transmitter. However, in packet- or burst-based radio systems, signals are transmitted in (short) bursts. In that case, synchronization is required at the beginning of each burst. A fast synchronization technique is therefore essential in order to minimize the overhead in the burst. As long as synchronization has not been finalized, the demodulation of the information stream is impaired by errors even under high signal-to-noise conditions.

Synchronization is required since the frequencies and the timing used in the transmitter and receiver are not exactly aligned. A frequency offset in the receiver results in received signals which are not exactly in the center of the receive filters, in rotating constellations, and in accumulating phase errors. A timing offset results in sampling of the symbols at non-ideal moments in time thus being more susceptible to noise and interference. Synchronization schemes can be divided into two types. The so-called data-aided synchronization schemes make use of a known symbol sequence at the beginning or in the middle of the information stream, e.g. in the packet. The known symbol sequence is either at the beginning of the packet as shown in Figure 1. (examples are found in radio systems based on Bluetooth, WLAN 802.11, and HIPERLAN2) or in the middle as shown in Figure 1b (an example is found in the GSM system). The known data stream is used to "train" the receiver; that is, to help the receiver to determine frequency and timing offsets. The known sequence is therefore also called a training sequence. This training sequence provides overhead in the communication channel and should therefore be minimized. That is, the number of symbols used for the training sequence should be as small as possible. The other synchronization type is called the non-data-aided synchronization scheme. This scheme does not use an explicit training sequence, instead the user information stream itself is used to train the receiver. This method requires delay: initially, the received information stream can only be used for training and cannot be demodulated. The received stream must be stored to be demodulated later when the receiver has been trained. Note that a minimum packet length is required: the number of symbols in the packet should at least be sufficient for the receiver to train on. Non-data aided synchronization schemes do not provide the overhead inherent to data-aided synchronization schemes, although a small frame-delimiter is required to determine the start of the packet. One can argue that a form of non-data aided synchronization is always applied even in data-aided schemes: after the (coarse) synchronization has been established, in most cases the receiver parameters are continuously updated which we call tracking. Tracking uses the user information symbols as well. This can be considered as a form of fine synchronization using information symbols only. During tracking, the parameter estimates are sufficiently accurate to demodulate the received information symbols as well. Synchronization (coarse tuning) and tracking (fine tuning) are closely related.

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It is the intention of this patent to provide a technique to speed up the synchronization process. In fact, the intention is to start tracking as soon as possible. Since tracking can be applied on user information that is directly demodulated, this will reduce the overhead in data-aided synchronization schemes and reduce the storage requirements and minimum packet length in non-data aided schemes.

3. SUMMARY

Synchronization consists of a coarse tuning phase and a fine tuning case, after which demodulation and tracking can be started. As more data symbols arrive at the receiver, the more accurate can the receiver determine the frequency and timing parameters and the more accurate (read lower error probability) the demodulation process can be carried out. Instead of waiting until coarse and fine tuning have been finalized before demodulation is started, the current patent proposes to start demodulation as quickly as possible but to make the start of the packet more robust. The lack of accuracy in the synchronization parameters is therefore compensated by the robustness of the information stream. As more information symbols arrive, the synchronization parameters will be more accurate and the robustness in the information stream can gradually be reduced. Robustness can for example be provided by applying more forward-error correcting coding at the beginning of the packet and gradually removing the coding bits when progressing into the packet. Or it can be provided by using more robust modulation schemes at the beginning of the packet and gradually switching to more complex modulation when progressing into the packet, or a combination of modulation and coding (also including trellis-coded modulation). The reduction of the robustness follows a known pattern and does not require extra signaling (overhead) from the transmitter to the receiver.

4. LIST OF FIGURES

Figure 1. Examples of packets with explicit training sequences to help the synchronization process with either a) the synchronization word in the beginning b) or the synchronization word in the middle of the burst.

Figure 2. Diagram showing a) the error in synchronization process versus number of symbols received, and b) the demodulation process on the received symbols according to the conventional synchronization operation.

Figure 3. Diagram showing a) the error in synchronization process versus number of symbols received, b) the reduction in robustness versus number of symbols received, and according to the present invention c) the demodulation process on the received

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symbols according to the present invention.

Figure 4. Example of the increase in coding rate using block codes according to a first embodiment of the present invention.

Figure 5. Example of the increase in coding rate using punctured convolution coding according to a second embodiment of the present invention..

Figure 6. Example of the increase of modulation complexity according to a third embodiment of the present invention.

Figure 7. Example of the increase trellis-coded modulation complexity according to a fourth embodiment of the present invention.

Figure 8. Example of the increase in coding rate using punctured convolution coding, according to a fifth embodiment of the present invention.

5. DETAILED DESCRIPTION OF THE INVENTION

The current disclosure describes a method and apparatus for providing extra robustness to a radio packet to speed up the synchronization process and start the tracking process as fast as possible. During synchronization, the receiver tries to estimate a number of crucial signal parameters in the radio signal received, for example the frequency, the phase, the symbol timing, and the frame timing. For coherent detection, all parameters are of importance, for non-coherent detection, the phase information is less important. A reasonable accuracy in the parameter estimates must be obtained before the demodulation can be started. Errors in the parameter estimates give rise to symbol errors during the demodulation process. The error in the parameter estimates is a function of the received symbols, as shown in Figure 2a. As more symbols are received, more signal energy for the synchronization process is received and the accuracy in the estimates increases. If the error in the parameter estimates has arrived below an acceptable level Δ1, the receiver can start demodulating the received symbols. The receiver then has already received N1 symbols. For a non-data-aided scheme, any formerly received and stored symbols can now be demodulated, as well as all symbols received in the future. The inventive concept of the current disclosure is illustrated in Figure 3. Instead of waiting for N1 symbols until the error level has decreased to below Δ1, the receiver already starts demodulating when N2 (N2<N1) symbols have arrived and the error is still Δ2 (Δ2>Δ1), see Figure 3a and 3b. In order to reduce the symbol error probability Ps under the Δ1 inaccuracy conditions to the same symbol error probability as obtained under the Δ2 inaccuracy conditions, additional robustness is added to the symbols in the packet, see Figure 3c. As more symbols are received and the error in the estimates is further reduced, the additional robustness is removed. When the error has reduced until Δ1, no more additional

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robustness is required. With the proposed method, the synchronization time has been reduced from N1 to N2; tracking already starts at N2.

The additional robustness that is added and gradually removed, can be applied in a number of forms. Most obvious methods are the deployment of forward-error correcting (FEC) coding and/or changing the modulation format. An example of the gradual diminishing FEC code technique is shown in Figure 4. The illustrated technique can be applied in a packet in combination with a non-data-aided synchronization scheme or a data-aided synchronization scheme with a training sequence at the start of the packet. In this case, a block coding technique was assumed: blocks of K symbols are mapped to a code word of length M with M>K (M-K is the number of parity bits). The ratio K/M is the code rate: the lower the code rate, the more parity bits are present and the more robust the symbols are. In the example of Figure 4, four segments are used; for each segment a different coding rate was selected. In this example, BCH codes with a constant M=63 (block length) and an increasing number K=11, 24, 36, 45 (information bits) were applied. The number of four segments was chosen as an example but in general any number of segments can be used. In addition, block codes different from BCH can be used. The number of segments and the number of symbols in each segment are design parameters and can be optimized regarding the modulation, coding and synchronization methods. Note also that the division into segments does not have to be related to the known training sequences or the contents of the packet. It is only related to the synchronization and tracking performance. The FEC code rate increases for each additional segment; so the robustness decreases for each segment with a higher number. The number of segments and number of symbols per segment are design constants and are known to both the transmitter and the receiver. Therefore, this information does not have to be signaled from the transmitter to the receiver. The last segment contains the remainder of the packet; in this segment, the coding applied is identical to the coding situation in the conventional scheme; that is, no additional coding is added. In Figure 5, a situation similar to Figure 4 is shown. However, instead of block coding, convolutional coding with puncturing is applied. In this case, no discrete segments are necessary. Instead, a puncturing scheme can be used where gradually symbols are removed at a higher rate. Again, the puncturing pattern is a design parameter known to both the transmitter and the receiver.

Instead of using a FEC coding at the beginning of a packet, more robust modulation schemes can be selected at the beginning of the packet. In Figure 6, it is illustrated how the beginning of the packet is divided into segments, where in each segment a different modulation is used. For lower segment numbers, more robust schemes are used; that is, schemes less sensitive to frequency and/or phase and/or timing errors. The FEC and modulation can also be applied together. Either for each segment a separate FEC rate and modulation are selected, or a combined FEC/modulation scheme or coded-modulation scheme is selected; this is also called trellis-coded modulation (TCM). An example of the latter is shown in Figure 7. This example starts with a modulation scheme with a small number of constellation points.

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For additional segments, more complex modulation schemes are used (more constellation points); the code rate is first reduced and then increases.

Finally, the technique of additional robustness when synchronization parameters are not yet accurate has been shown for a non-data-aided synchronization technique or for a data-aided synchronization technique with the training sequence at the beginning of the packet. In Figure 8, the situation is depicted for a data-aided synchronization technique with the training sequence in the center of the packet. In this case, the payload is demodulated from the center. Robustness must be added to the information symbols closest to the training sequence. In Figure 8, an example with punctured convolutional coding is shown. It will be understood that adding robustness with any other of the above-mentioned techniques can equally well be applied.

It will be understood that the proposed schemes automatically adapt to varying packet lengths. For example, in Figure 4, there are four segments in four different coding rates. The packet can be shortened without any impact on the performance. If the packet is shortened, later segments automatically cancel. So in Figure 4, a very short packet may use segments I and II only, or segment I only.

Other techniques that provide robustness to the symbols that differ from FEC coding and robust modulation may be used. Note also that the reduction in robustness does not necessarily bear any relation to the information contents in the packet. For example, the segment boundaries do not have to align with boundary fields in the packet (like a synchronization word or a packet header, for example).

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